

Electrical and optical properties of Si- and Mg-doped polycrystalline GaN on quartz glass substrate

H. Tampo, H. Asahi, M. Hiroki, Y. Imanishi, K. Asami and S. Gonda
Osaka University, ISIR, 8-1, Mihogaoka, Ibaraki, Osaka 567-0047, Japan
Tel: +81-6-6879-8406, Fax: +81-6-6879-8509, E-mail: tampo21@sanken.osaka-u.ac.jp

GaN material system is gathering great interest from the viewpoints of their application to optical devices as well as electronic devices. Recently, we have studied the growth of GaN layers on amorphous quartz (silica) glass substrates, and observed strong PL emission without deep-level emission in spite of their polycrystalline structure [1-3].

In this paper, we will report the results on further optimization of growth condition and Si and Mg doping studies. In the previous study [4], it was found that the polycrystalline GaN layers grown on silica (quartz) substrate those grown under the (1×1) RHEED condition for the single crystalline GaN on sapphire substrate show stronger PL emission and stronger c-orientation nature than under the (2×2) RHEED condition, and Si-doped n-type and Be-doped p-type layers were demonstrated [4]. Si-doped and Be doped layers showed electron and hole concentrations of 4×10^{17} to $7 \times 10^{16} \text{ cm}^{-3}$, respectively.

By further optimizing the growth temperature and Ga/N₂ ratio, we have obtained high quality polycrystalline GaN growth condition on glass substrate. They showed strong and narrow PL spectra: their PL peak energy and full width at half maximum (FWHM) were the same as those (3.48 eV at 77K and ~30 meV) of single crystalline GaN on sapphire. The PL intensities for these polycrystalline GaN on glass substrate were comparable to that of Si-doped single crystalline GaN grown on sapphire by MOVPE at Nichia Chemical Co. Ltd. [4]. Undoped polycrystalline GaN grown here under the optimized growth condition showed high resistivity. On the other hand, undoped previously grown polycrystalline GaN showed n-type conduction ($\sim 1 \times 10^{17} \text{ cm}^{-3}$). In this study, n-type (Si) and p-type (Mg) doping experiments were conducted on the polycrystalline GaN grown under the optimized growth condition. By regulating the Si cell temperature from 958 to 1098 °C, we obtained n-type polycrystalline GaN layers with electron concentration of from 1.3×10^{17} to $2.7 \times 10^{18} \text{ cm}^{-3}$ as shown in Fig. 1. We observed the PL spectra shown in Fig. 2 for these samples. With the increase in electron concentration, the FWHM of the 77K PL transition increases from 160 to 300 meV, and the PL peak energy shifted toward lower energy. The luminescence line broadening is considered to be due to potential fluctuation caused by the random distribution of doping impurities [5]. The PL peak shift is considered to be due to the bandgap narrowing effect by Si doping [6]. Large peak shift may also suggest the large potential fluctuation due to the grain-to-grain discontinuity. Mg doping experiments was also conducted and we successfully obtained the p-type polycrystalline GaN layer with a hole concentration of $2.5 \times 10^{17} \text{ cm}^{-3}$. Fig. 3 shows PL spectrum for the Mg-doped polycrystalline GaN at 77K. The broad emission at 3.19 eV was considered to be attributed to the free electron-acceptor transitions in GaN:Mg [7]. In summary, we obtained the high quality polycrystalline GaN on glass substrate by optimizing the growth condition. We also obtained n-type and p-type polycrystalline GaN by Si and Mg doping with an electron concentration of between 1.3×10^{17} to $2.7 \times 10^{18} \text{ cm}^{-3}$ and a hole concentration of $2.5 \times 10^{17} \text{ cm}^{-3}$, respectively.

Reference

- [1] K. Iwata, H. Asahi, K. Asami, R. Kuroiwa and S. Gonda, Jpn. J. Appl. Phys. **36** (1997) L661
- [2] K. Iwata, H. Asahi, R. Kuroiwa, K. Asami and S. Gonda, J. Crystal Growth **188** (1998) 98
- [3] K. Iwata, H. Asahi, K. Asami, A. Ishida, R. Kuroiwa, H. Tampo and S. Gonda, J. Crystal Growth **189/190** (1998) 218
- [4] H. Asahi, K. Iwata, H. Tampo, R. Kuroiwa, K. Asami, S. Nakamura and S. Gonda, J. Crystal Growth **201/202** (1999) 371
- [5] E. F. Schubert, I. D. Goepfert and W. Grieshaber Appl. Phys. Lett. **71** (1997) 921
- [6] Xiong Zhang, Soo-Jin Chua, Wei Liu and Kok-Boon Chong Appl. Phys. Lett. **72** (1998) 1890
- [7] M. Smith, G. D. Chen, J. Y. Lin, H.X.Jiang, A. Salvador, B.N Sverdlov, A. Botchkarev, H. Morkoc and B. Goldenberg, Appl. Phys. Lett. **137** (1990) 1639

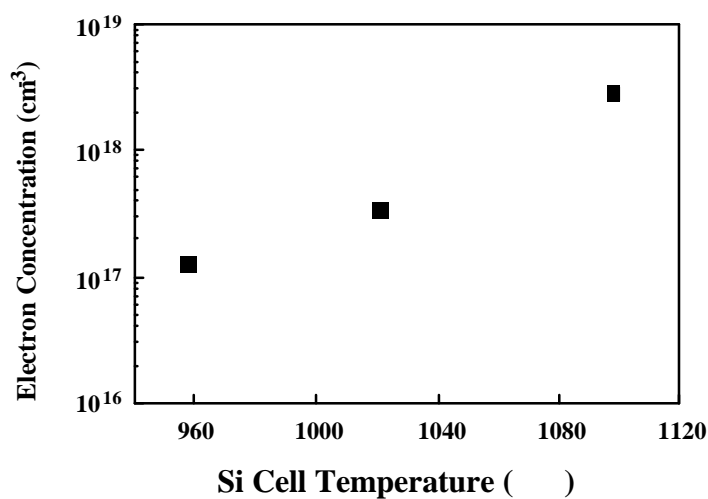


Fig. 1 Dependence of electron concentration on Si cell temperature.

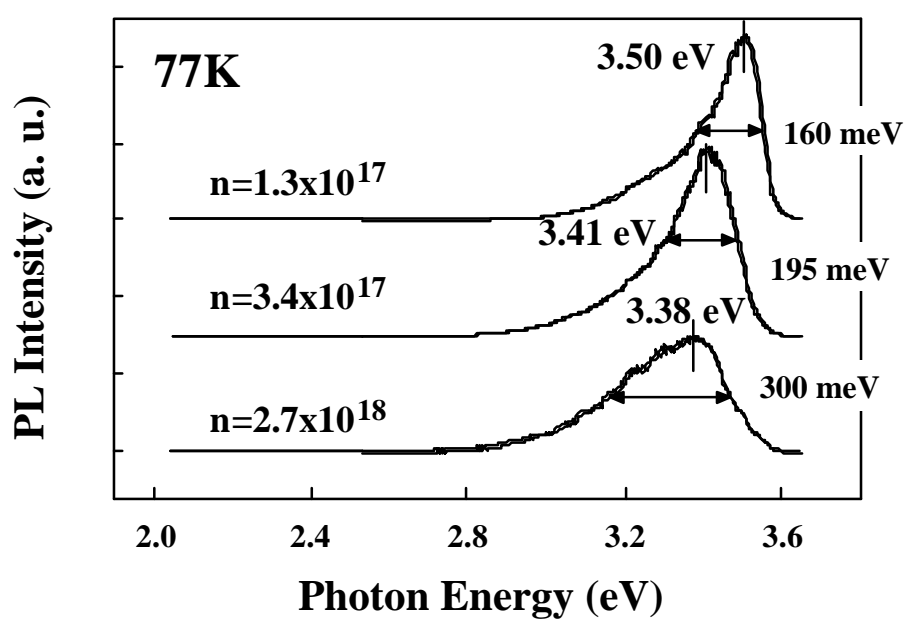


Fig.2 77K PL spectra for Si-doped GaN with different electron concentration.

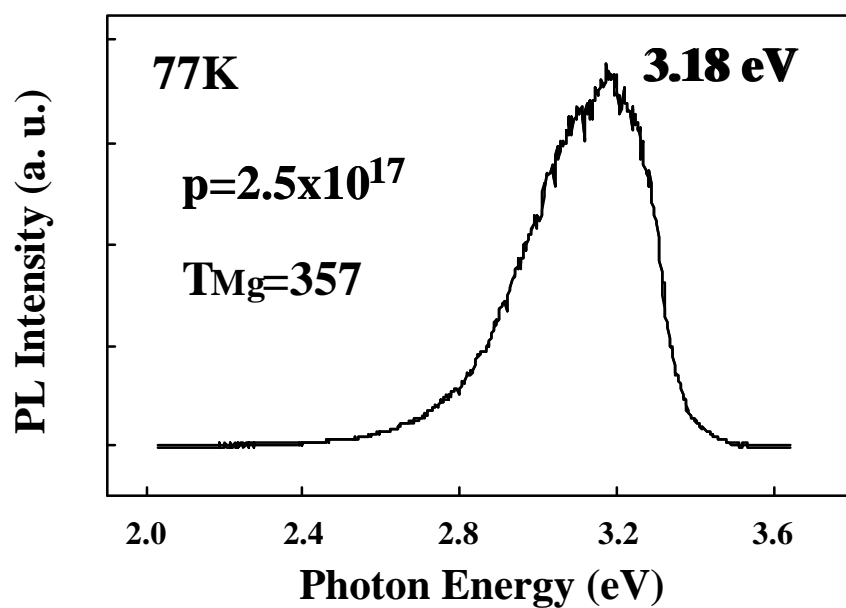


Fig.3 PL spectrum for Mg-doped polycrystalline GaN at 77K.